TransAID

V2X solutions for infrastructure-assisted automated driving

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in www.linkedin.com/groups/13562830/
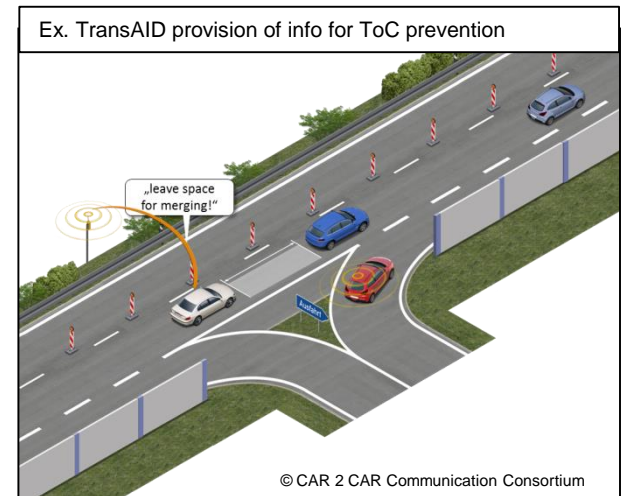f www.facebook.com/transaidh2020/

MAVEN and TransAID scope

☐ **MAVEN:** V2X-assisted traffic management of CAVs at signalized intersections and intersection corridors

- I2V interactions for traffic light controller and flow optimization
- Flexible urban platooning
- Consideration of non-cooperative traffic and VRUs
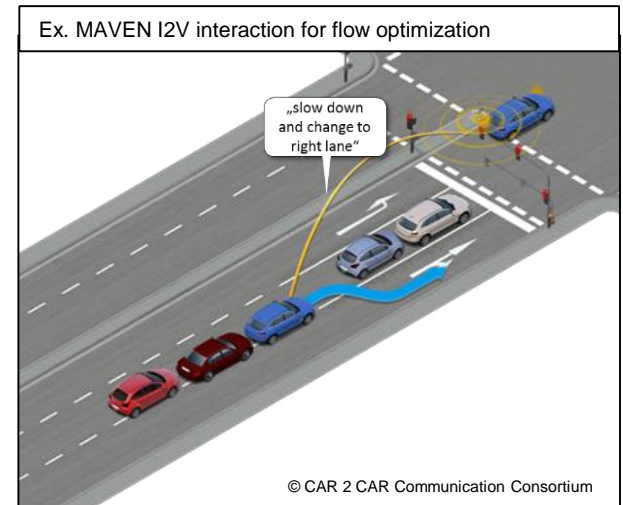
☐ **TransAID:** V2X-assisted traffic management of CAVs at transition areas (in presence of other vehicle types):

- Manage transition of vehicles
- Distribute transitions of vehicles in time and space
- Prevent transitions by providing supporting information

Ex. MAVEN I2V interaction for flow optimization

„slow down and change to right lane"

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Ex. TransAID provision of info for ToC prevention

„leave space for merging!"

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Designing suitable V2X message sets

❑ V2X messages are cornerstone for I2V-assisted traffic management

❑ Nevertheless, their suitability strongly depends on:

  – Reuse of existing standards → **interoperability** and fast industrial adoption

  – Support for backwards compatibility → **service sustainability** as new extended messages keep conveying information needed by already deployed systems

  – Reasonable use of radio resources → **QoS preservation** by minimizing congestion possibilities

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MAVEN and TransAID message sets

Extension

Proposal

Optimization

Profiling

| CAM | DENM | MCM | CPM | MAPEM/ SPATEM | IVIM |

Cooperative Awareness Message
staus and dynamics

Decentralized Environmental Notification Message
Possible hazards

Maneuver Coordination Message
Support info for driving/traffic coordination

Collective Perception Message
Locally detected objects

MAP and Signal Phase & Time Message
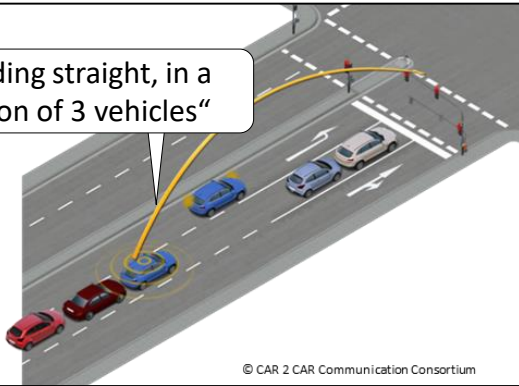Road topology & traffic light controller info

In-Vehicle Message
Static and dynamic traffic signs & info

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CAM extensions (1)

❑ Need: increase infra awareness about vehicle statuses, properties, intentions, relationships
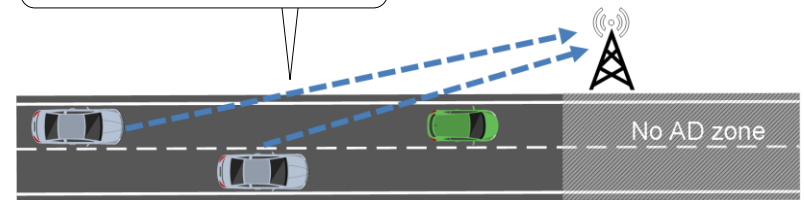
Ex. MAVEN	Ex. TransAID

„heading straight, in a platoon of 3 vehicles"

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„in AD mode and at 60m from front car"

No AD zone

Traffic light controller can compute more granular and stable phase timing plans and speed advices

Infra understands what cars need advices for transition of control management and achieves global knowledge for their computation

❑ Solution: Automated Vehicle Container inclusion in SCH0 CAM

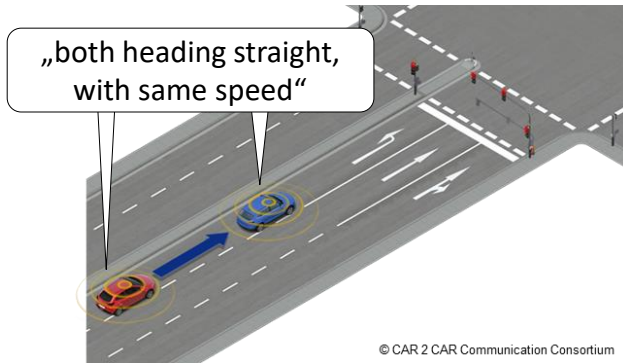| Extended CAM	CoopAwareness	CAMParameters	ItsPduHeader
			GenerationDeltaTime
			BasicContainer
			HighFrequency Container = BasicVehicleContainerHighFrequency
			LowFrequencyContainer = BasicVehicleContainerLowFrequency
			SpecialVehicleContainer = AutomatedVehicleContainer

Includes needed info:
- CAV route at intersection
- Distance to preceding/following vehicle
- Platoon Id & participants…

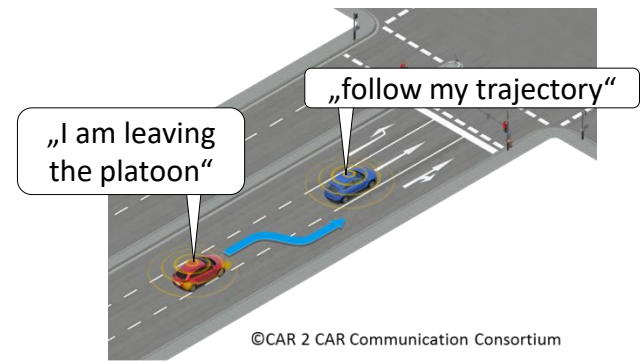**Backwards compatible**: can be discarded by legacy cooperative vehicles

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CAM extensions (2)

❑ Need: detect possibilities for platoon initialization and manage platoon operations

Ex. MAVEN

"both heading straight, with same speed"

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"I am leaving the platoon"

"follow my trajectory"
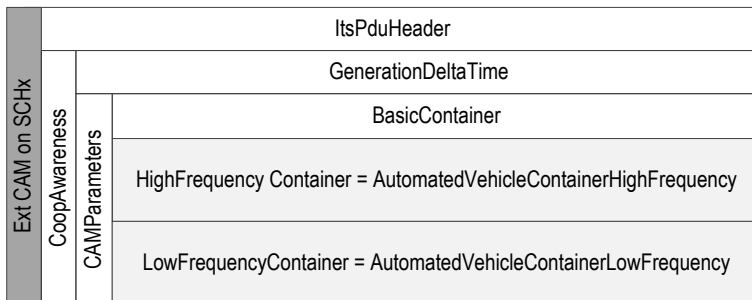
©CAR 2 CAR Communication Consortium

Criteria for initialization met: a platoon can be formed

CAVs can safely drive in platoon formation and manage operations (e.g. leaving) in a distributed way (platoon state machines)

❑ Solution: High & Low frequency Automated Vehicle Container in SCHx CAM

| Ext CAM on SCHx	CoopAwareness	CAMParameters	ItsPduHeader
			GenerationDeltaTime
			BasicContainer
			HighFrequency Container = AutomatedVehicleContainerHighFrequency
			LowFrequencyContainer = AutomatedVehicleContainerLowFrequency

Include needed info:
- More frequent vehicle position, dynamics and planned trajectory
- Flags adopted by platooning state machine

Backwards compatible and resource effient: transmitted on parallel channel of that of legacy cooperative vehicles (SCH0)

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DENM extensions

❑ Need: warn legacy cooperative vehicles about CAVs in ToC/MRM

Ex. TransAID

Legend:

Connected vehicle

Cooperative Automated vehicle

ToC

No AD zone
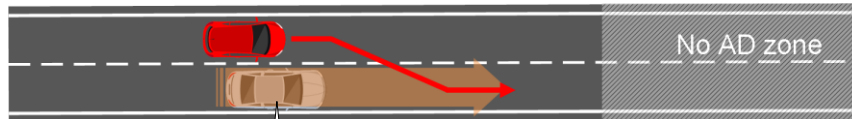
„I am executing a ToC and eventually a MRM in t1 and t2 s"

Connected vehicle is warned and driver will interrupt attempts of lane change in conflicting zone

❑ Solution: Extend situation container with Event Types related to ToC and MRM

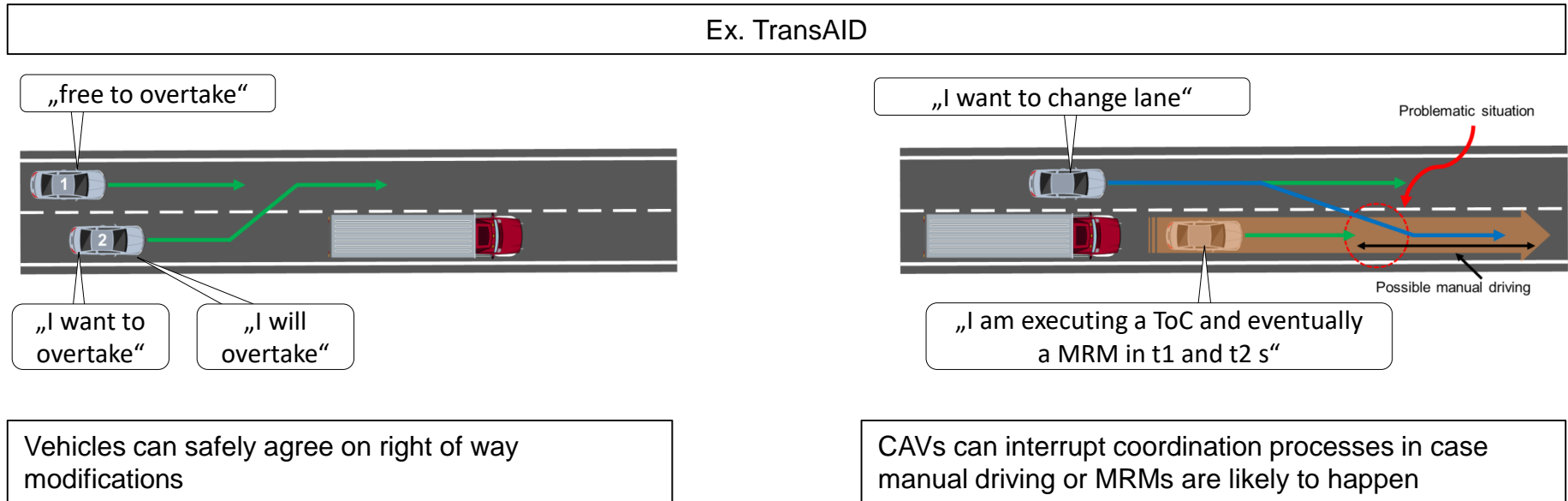| Extended DENM	DENM	ItsPduHeader
		ManagementContainer
		SituationContainer
		LocationContainer
		AlaCarteContainer

Includes needed info:
- ToC alert
- MRM alert

Backwards compatible: can be discarded by legacy cooperative vehicles

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Maneuver Coordination proposal (1)

❑ Need: enable conflict-free V2V maneuver coordination and prevent risks associated to ToC

Ex. TransAID

"free to overtake"

"I want to change lane"

Problematic situation

"I want to overtake"

"I will overtake"

"I am executing a ToC and eventually a MRM in t1 and t2 s"

Possible manual driving

Vehicles can safely agree on right of way modifications

CAVs can interrupt coordination processes in case manual driving or MRMs are likely to happen

Legend:

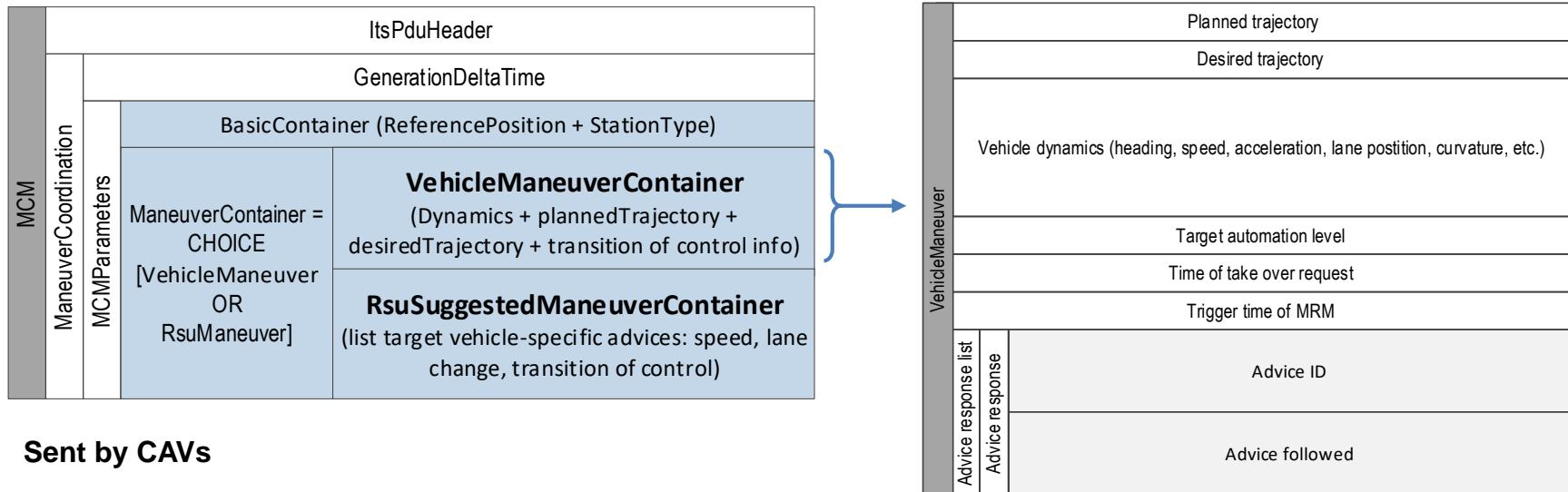Cooperative Automated vehicle

Planned trajectory

Desired trajectory

ToC

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Maneuver Coordination Proposal (2)

❑ Solution: extension of ETSI Proposal by inclusion of ToC info in Vehicle Maneuver Container

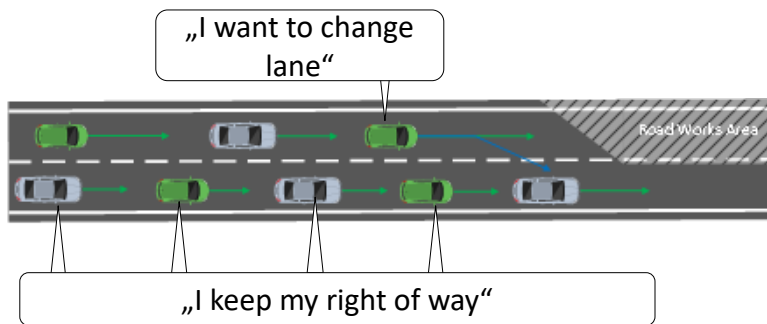**Sent by CAVs**

Includes needed info:
- Planned trajectory
- Desired trajectory
- Vehicle dynamics
- Information about future ToC
- Acknowledgement of I2V advice acceptance (see next slides)

Vehicle decides if the advice can be followed
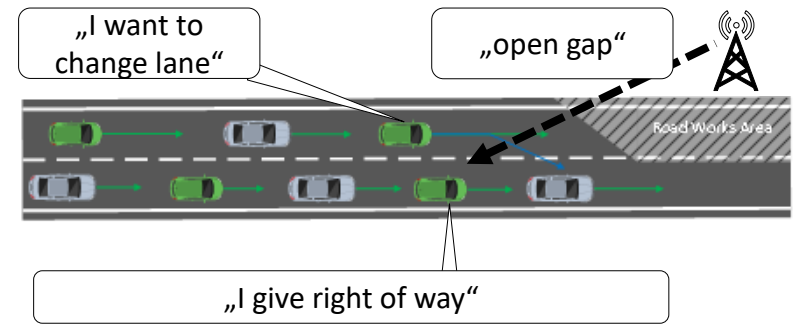**Totally compatible with current ETSI approach**

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Maneuver Coordination proposal (1)

❑ Need: optimize overall traffic flow by preventing bottlenecks due to egoistic implementation of right of way

Ex. TransAID

„I want to change lane"

„I want to change lane" „open gap"

Road Works Area

„I keep my right of way"

„I give right of way"

Vehicles on left lane never get right of way and are stuck at the roadworks

Infra suggest individualized measures (e.g.) gap advices to prevent bottlenecks

Legend:

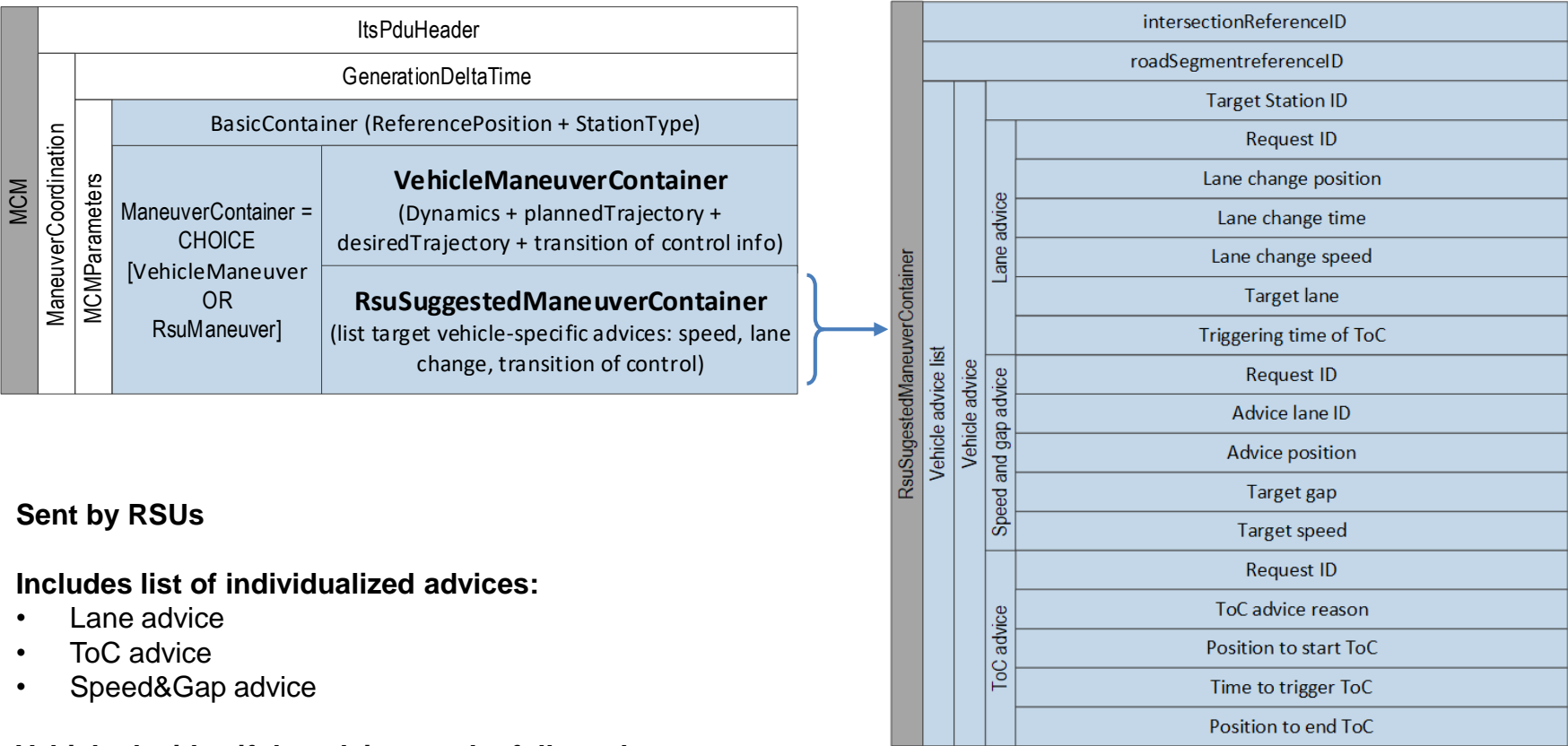Cooperative Automated vehicle   Planned trajectory   Desired trajectory   ToC   I2V

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Maneuver Coordination Proposal

❑ Solution: extension of ETSI Proposal by RSU Suggested Maneuver Container

			ItsPduHeader
MCM	ManeuverCoordination	MCMParameters	GenerationDeltaTime
			BasicContainer (ReferencePosition + StationType)
		ManeuverContainer = CHOICE [VehicleManeuver OR RsuManeuver]	**VehicleManeuverContainer** (Dynamics + plannedTrajectory + desiredTrajectory + transition of control info)
			RsuSuggestedManeuverContainer (list target vehicle-specific advices: speed, lane change, transition of control)

RsuSugestedManeuverContainer	Vehicle advice list	Vehicle advice	Lane advice	intersectionReferenceID
				roadSegmentreferenceID
				Target Station ID
				Request ID
				Lane change position
				Lane change time
				Lane change speed
				Target lane
				Triggering time of ToC
			Speed and gap advice	Request ID
				Advice lane ID
				Advice position
				Target gap
				Target speed
			ToC advice	Request ID
				ToC advice reason
				Position to start ToC
				Time to trigger ToC
				Position to end ToC

Sent by RSUs

Includes list of individualized advices:
*   Lane advice
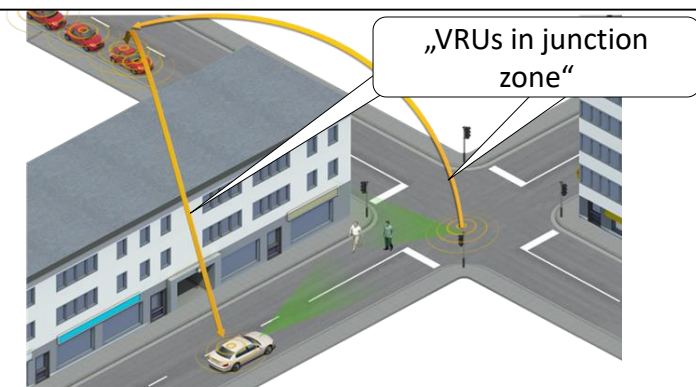*   ToC advice
*   Speed&Gap advice

Vehicle decides if the advice can be followed
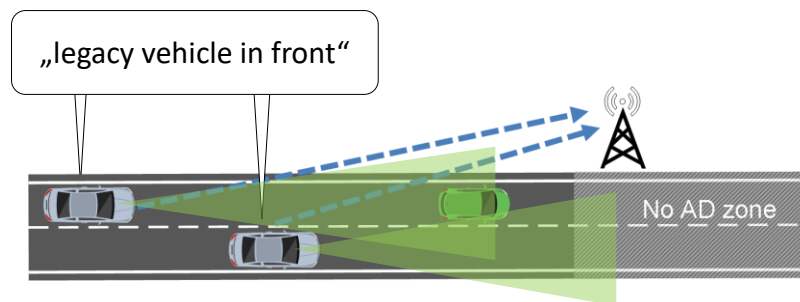
Totally compatible with current ETSI approach

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CPM optimization (1)

❑ Need: increase overall awareness about non-cooperative road users presence

Ex. MAVEN

„VRUs in junction zone"

Vehicles behind the corner get notified about presence of hidden obstacles and can operate preventive reactions (e.g. slowdown)

Ex. TransAID

„legacy vehicle in front"

No AD zone

Infra in informed about legacy vehicle presence, which is reused for computation of traffic management measures

❑ Solution: Adoption of currently available ETSI approach

CPM	CollectivePerception	CPMParameters	
			ItsPduHeader
			GenerationDeltaTime
			OriginatingStationContainer (either vehicle or RSU)
			SensorInformationContainer (either vehicle or RSU)
			PerceivedObjectContainer

Includes needed info:
- Info about sender position
- Info about sensing capabilities (FoV, ranges)
- Info about object description (rel. position, speed,…)

Suitable for vehicle or Infra-based detection:
Contributions by MAVEN on RSU-specific definitions

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CPM optimization (2)

❑ Evaluation of the current ETSI CPS standard as a baseline for optimization:

– Study the implications of ETSI CPS on V2X network stability:

- In-depth performance evaluation considering forward and 360⁰ sensors.

- Analysis of CPM rate & size.

- Communications performance.

- CPM awareness and redundancy.

❑ Results presented at ETSI. They are part of ETSI TR 103.562.

CPM optimization (3)

❑ ETSI CPM proposed generation rules:

– A new CPM is generated when:

   1. New objects are detected.

   2. Previously detected objects:

      a. Change its position by more than 4 meters.

      b. Change its speed by more than 0.5 m/s.

      c. Included in the last CPM 1 second ago.

– If no object detected: generate CPM once per second.

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CPM optimization (4)

❑ Analysis of CPM generation:

 – CPM generation rate depends on vehicle dynamics and traffic density.

 – Generation frequency decreases at higher traffic densities.

 – High CPM rate with low number of objects.

Low traffic density

High traffic density
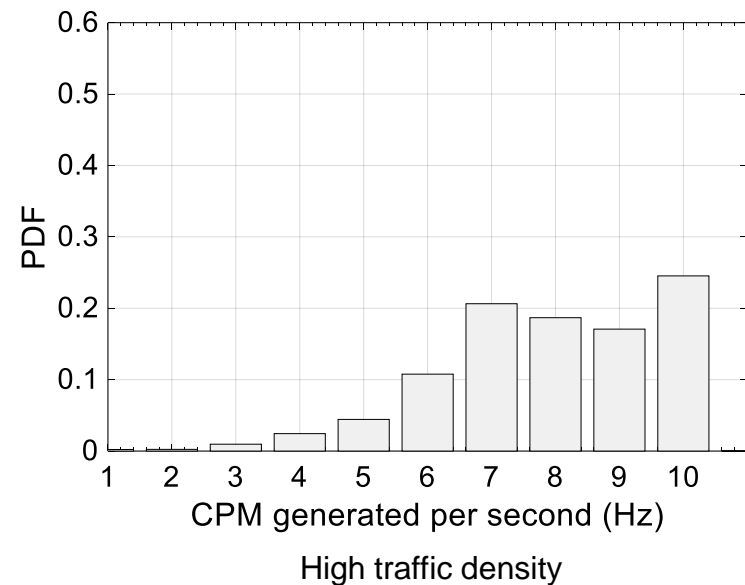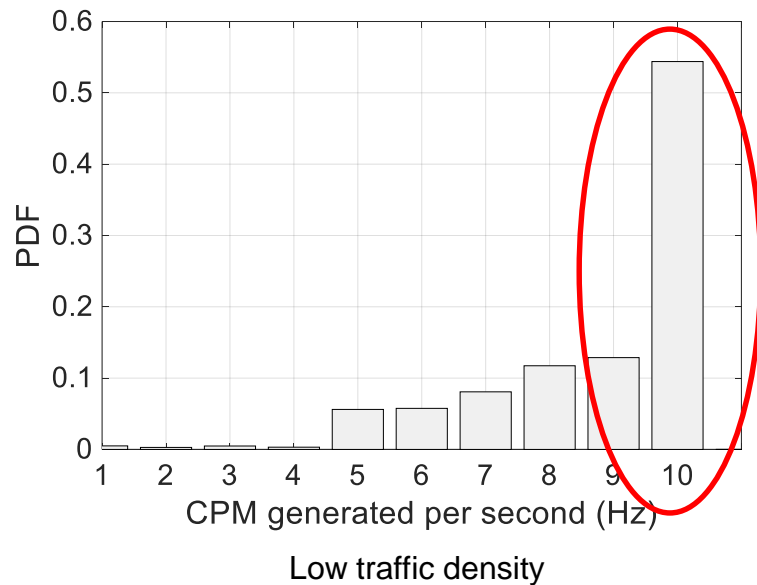
CPM optimization (5)

❏ Impact of CPM in the channel load:

  – Channel load increases with traffic density.

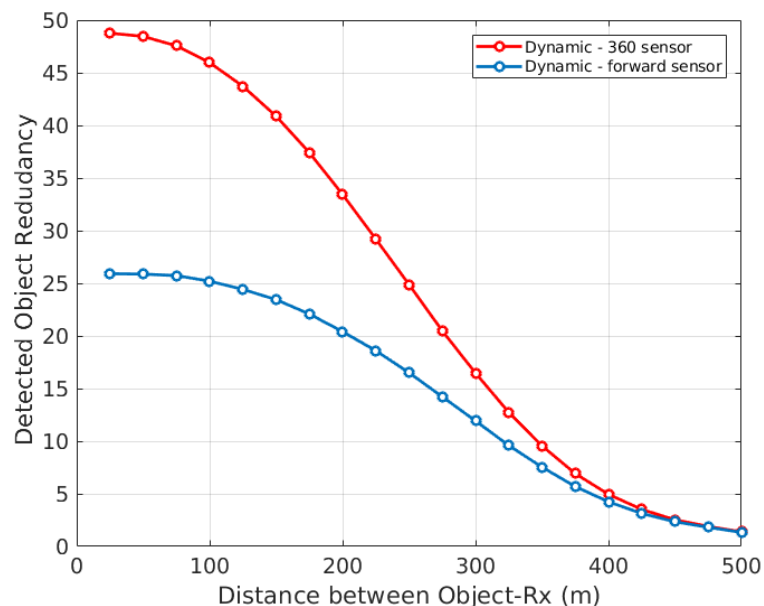 – The use of different sensors produces different channel loads.
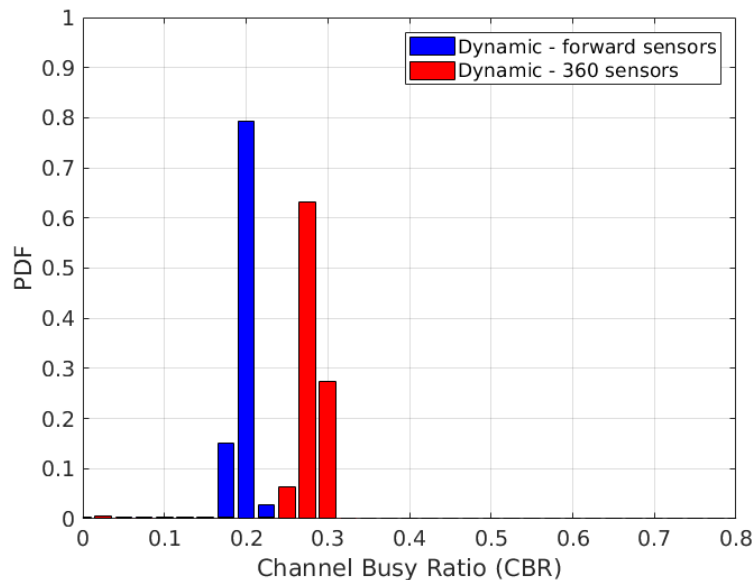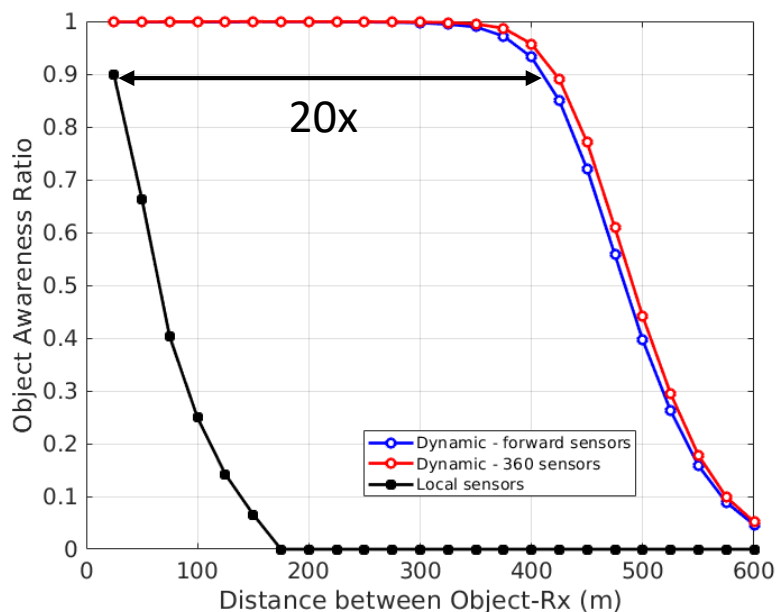

Low traffic density
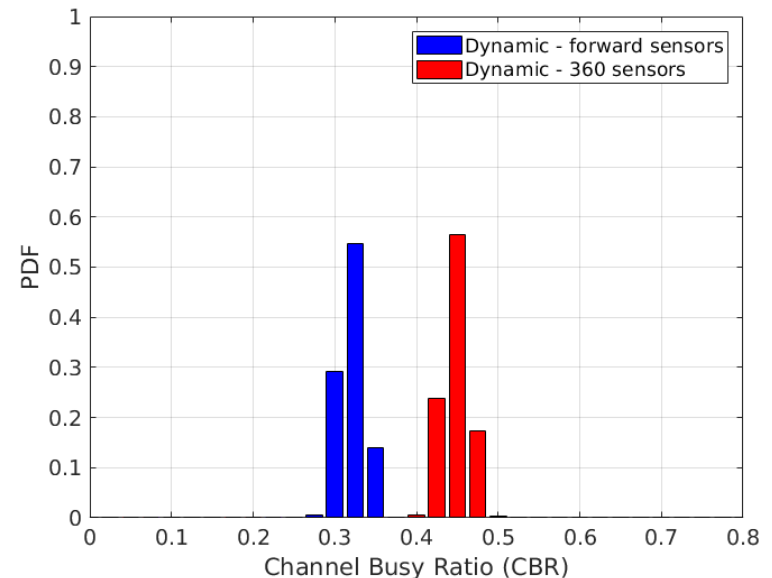
High traffic density

CPM optimization (6)

☐ CPM awareness and object redundancy:

- V2X communications increase awareness distance by a factor of 20.

- Same object received between 25 and 50 times per second.

- Can we reduce the redundancy without reducing the awareness?

TransAID Integrated Simulations (1)

❑ V2X assisted traffic management requires integrated simulations:

 – Vehicle behaviour influenced by V2X information received.

 – We need an integrated simulator platform:

  • Realistic traffic simulations.

  • Realistic communications simulation.

  • Interaction between traffic and communications simulations.

❑ iTETRIS platform:

 – Simulation cooperative ITS applications in large scale scenarios.

 – Open source platform.

 – TransAID updates to iTETRIS will be released at the end of the project.

TransAID Integrated Simulations (2)
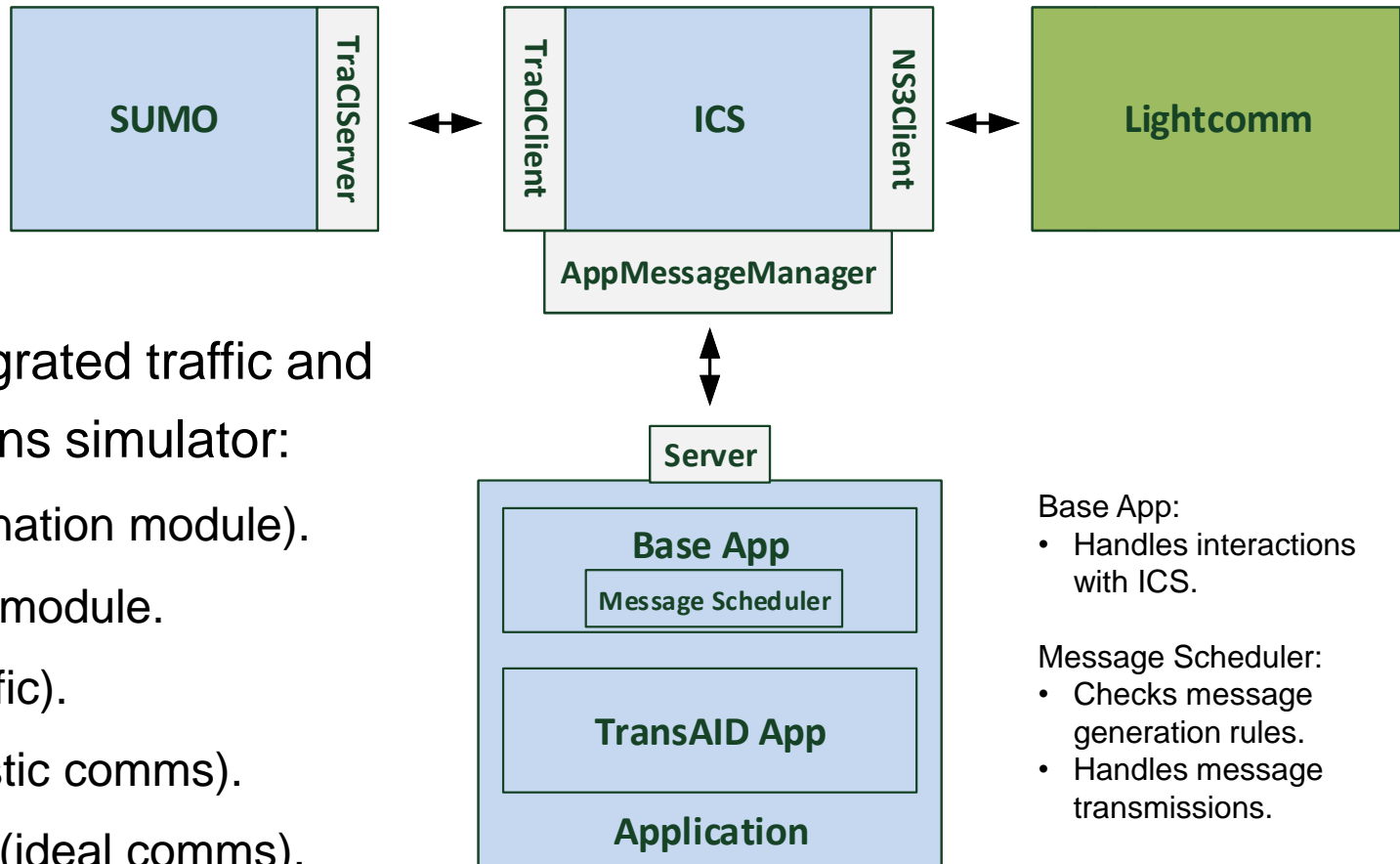
- ❑ iTETRIS: integrated traffic and communications simulator:
    - – iCS (coordination module).
    - – Application module.
    - – SUMO (traffic).
    - – NS-3 (realistic comms).
    - – Lightcomm (ideal comms).

Base App:
- • Handles interactions with ICS.

Message Scheduler:
- • Checks message generation rules.
- • Handles message transmissions.

TransAID Integrated Simulations (3)

❑ TransAID services tested with the iTETRIS platform:

   – Service 1: Prevent ToC/MRM by providing vehicle path information.

   – Service 2: Prevent ToC/MRM by providing speed, headway and/or lane advice.

   – Service 3: Prevent ToC/MRM by traffic separation.

   – Service 4: Manage MRM by guidance to safe spot (urban and motorway).

   – Service 5: Distribute ToC/MRM by scheduling ToCs.

❑ Each service has been simulated for the following parameter combination:

   – 3 levels of service:

      • Urban: A:525, B:825 and C:1155 vehicles/h/lane.

      • Motorway: A:735, B:1155 and C:1617 vehicles/h/lane.

   – 3 different V2X penetration rates (30%, 50 % and 80%).
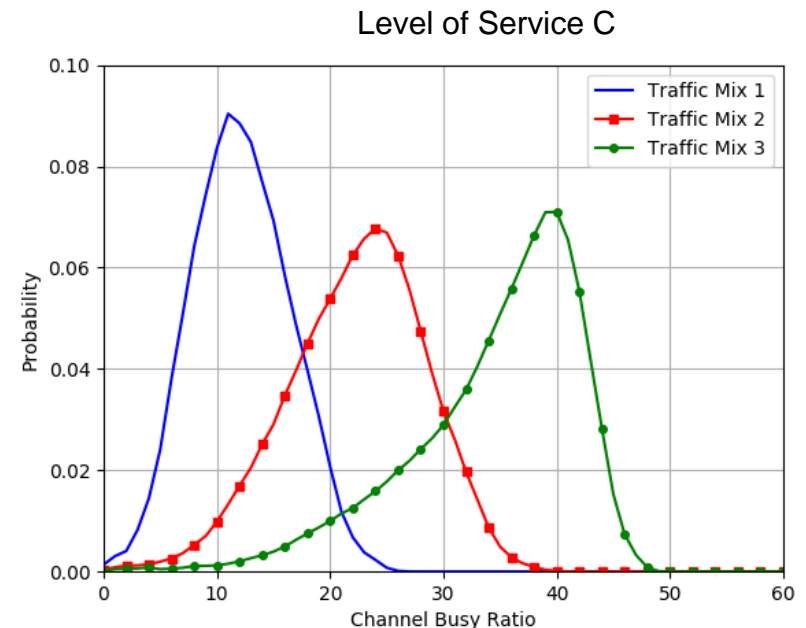
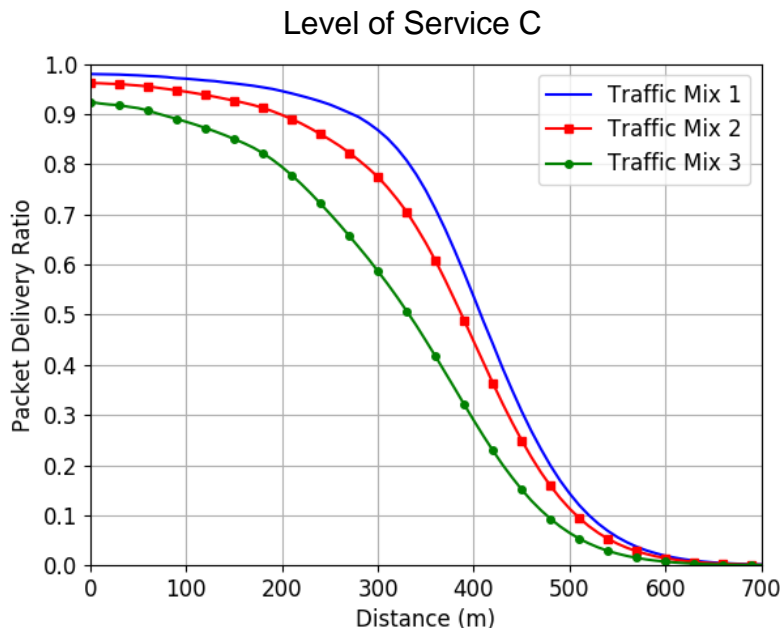   – Ideal and realistic communications.

TransAID Integrated Simulations (4)

❏ Example Service 4 (motorway):

- PDR decreases with V2X share.
- CBR increases with V2X share.
- Congestion control needed as V2X penetration rate increases.
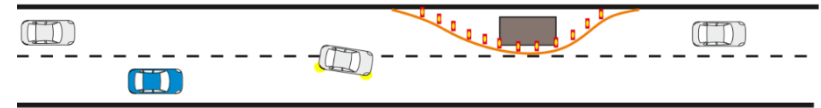
	LVs	CVs	CAVs
Traffic mix 1	70%	15%	15%
Traffic mix 2	50%	25%	25%
Traffic mix 3	20%	40%	40%

Level of Service C

Level of Service C

TransAID Integrated Simulations (5)

❑ Integrated simulations validate the design of TransAID Services:

  – Challenges will need to be adressed to avoid the loss of critical mesages.

    • Traffic disturbances can occur if infrastructure advices are lost.

  – Higher traffic demands or V2X shares will degrade communications performance.

⇩

Design techniques to ensure reliable exchange of V2X messages

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Reliable V2X message exchange (1)

❑ Compression of V2X messages.

   – Identification and implementation of potential compression techniques.

   – CAMs can be compressed up to 27% and CPMs up to 42%.

   – Compression/decompression is sufficiently fast for implementation.

❑ Integration of congestion control and message generation:

   – Impact of DCC on the awareness of CPM and effectiveness of MCM.

   – Challenges to handle multiple messages with different goals.

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Reliable V2X message exchange (2)

❑ Contribution to IEEE 802.11bd: Enhanced V2X technology

– Focus on improved link reliability, higher data rates, and longer range.

– Interoperability, coexistence, backward compatibility, and fairness with IEEE 802.11p standard.

– TransAID current work:

  • Following the 802.11bd standardization work and proposals made to date.

  • Reviewing other 802.11 amendments that could be integrated in 802.11bd.

  • Analysis of IEEE 802.11bd standardization proposals and IEEE 802.11 amendments to define future lines of work.

Conclusions

❑ V2X messages are cornerstone for I2V-assisted traffic management:

– Contributed to the standardization of ETSI V2X messages.

– Interoperability, backwards compatibility and QoS perservation.

❑ Evaluation and evolution of ETSI collective perception:

– Contribution to ETSI Technical Report 103 562.

❑ Integrated simulation of TransAID traffic management measures:

– TransAID services have been validated with iTETRIS (open source).

❑ Design techniques for reliable V2X message exchange.

– Contribution to standardization of IEEE 802.11bd.

Thanks for your attention!

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